FISHERY DATA SERIES NO. 75

ABUNDANCE AND AGE-SEX-SIZE COMPOSITION OF THE 1988 SALCHA RIVER CHINOOK SALMON ESCAPEMENT[1]

By

Cal Skaugstad

Alaska Department of Fish and Game
Division of Sport Fish
Juneau, Alaska 99802

January 1989

[1] This Investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

ABSTRACT

The number of adult chinook salmon *Oncorhynchus tschawytscha* that returned to spawn in the Salcha River near Fairbanks, Alaska, was estimated using a mark-recapture experiment. An electrofishing boat was used to capture 459 chinook salmon in July and early August, 1988. The chinook salmon were marked with jaw tags, finclipped, and released. In mid August, 873 fish were collected during carcass surveys. Of these fish, 92 had been marked during July and August. The distribution of lengths of the population was bimodal. The estimate of abundance was 4,562 (standard error = 556). The estimate of the number of females and males was 1,525 (standard error = 197) and 3,037 (standard error = 229). The peak count of chinook salmon from a fixed-wing aircraft was 2,761; about 61 percent of the mark-recapture point estimate. The estimate of egg production for the 1988 spawning run was 16.2 million eggs (standard error = 2.8 million).

KEY WORDS: chinook salmon, *Oncorhynchus tschawytscha*, enumeration, Salcha River, age-sex-size composition, aerial survey, fecundity, egg production, tag loss

INTRODUCTION

The complex nature of the escapement and exploitation of stocks of Yukon River chinook salmon *Oncorhynchus tschawytscha* requires that accurate estimates of escapement be made in a number of major spawning streams. The Salcha River, is a 250 km long clear runoff river flowing into the Tanana River about 60 km east of Fairbanks (Figure 1). The Salcha River is one of the most important chinook salmon producing streams in the entire Yukon River drainage.

Since 1972, the number of mature chinook salmon counted in the Salcha River during aerial surveys has ranged from 391 to 6,757 (Barton 1984). However, only a portion of the population is usually present during an aerial survey and the number of chinook salmon counted is affected by weather, water level, water clarity, and overhanging vegetation. Skaugstad (1988) found that the number of mature chinook salmon counted during an aerial survey of the Salcha River in 1987 was about 40 percent of the estimated population abundance based on a mark-recapture experiment. Barton (1987a, 1987b) found that the number of mature chinook salmon counted during an aerial survey was less than 20 percent of the estimated escapement based on mark-recapture experiments in the Chena River (near Fairbanks) and fish counts through a weir in Clear Creek (near Nenana).

The goal of this project was to determine what portion of the total spawner abundance, estimated using a mark-recapture experiment, was observed during an aerial survey of the Salcha River in 1988. The specific objectives in 1988 were to:

1. estimate the abundance of the population of spawning chinook salmon in the Salcha River using mark-recapture experiments;

2. estimate the proportion of the total escapement of chinook salmon in the Salcha River represented by a point estimate from an aerial survey during peak spawning; and,

3. estimate the age, sex, and size composition and total fecundity of the escapement of chinook salmon in the Salcha River.

MATERIALS AND METHODS

Capture and Marking

Adult chinook salmon were captured from 26 July through 2 August using a riverboat equipped with electrofishing gear (Clark 1985). The chinook salmon were stunned using pulsating direct current electricity, dipped from the river with long handled nets and placed in an aerated holding box. The lower 97 km of the river, up to the confluence with Caribou Creek, were sampled in this manner. Past aerial surveys of the Salcha River have shown that few chinook salmon spawn above Caribou Creek (Fred Anderson, Alaska Department of Fish and Game, Fairbanks, personal communication). The sample area was divided into three approximately equal sections (Figure 1). During the first marking event (26, 27, 29, and 30 July), one pass was made through sections 2 and 3 and two

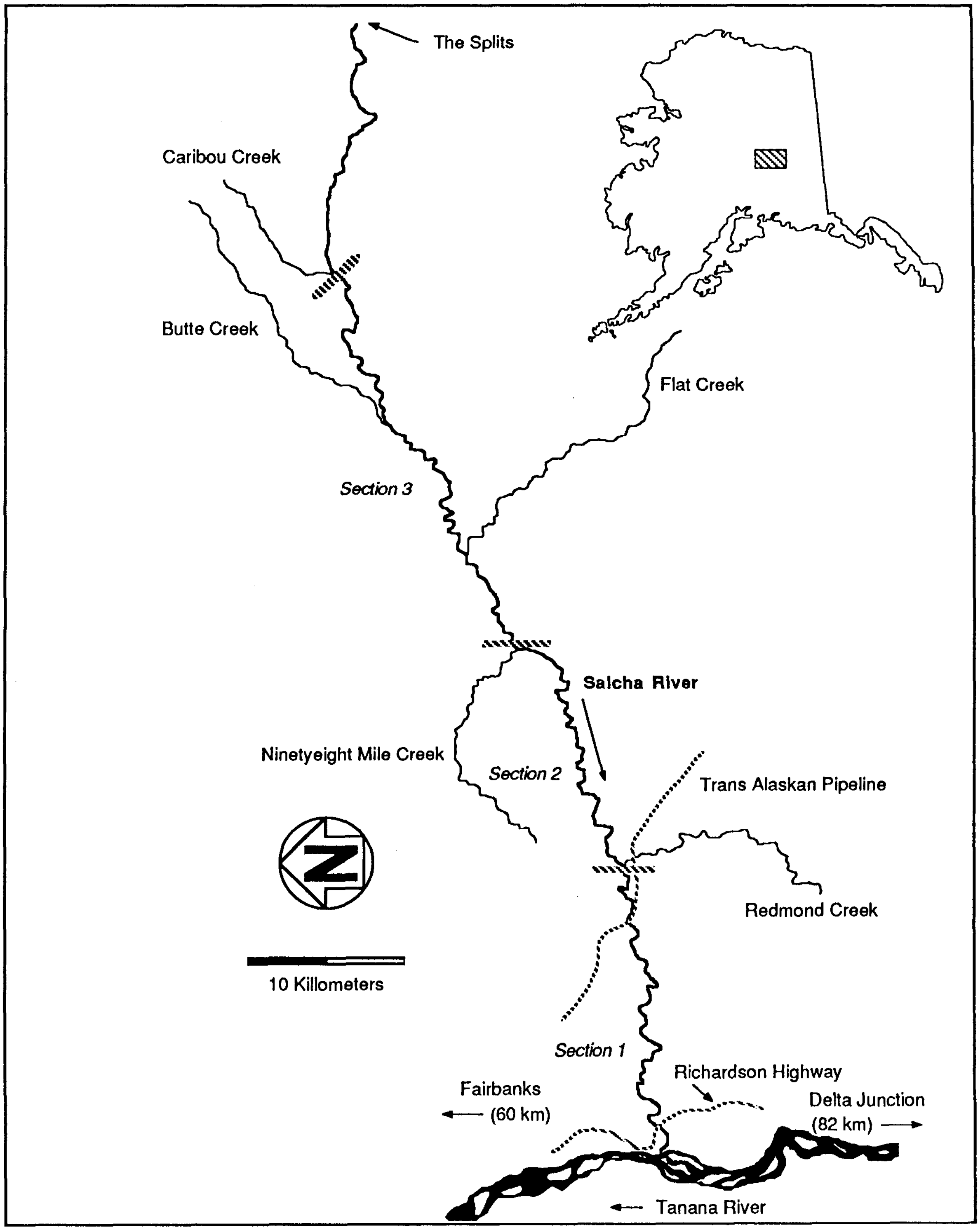

Figure 1. Salcha River study area.

passes were made through section 1. Each pass through a section started at the upstream end of the section. During the second marking event (1 and 2 August), one pass was made in all three sections. Both sections 1 and 2 were sampled on 2 August. Section 3 was sampled on 1 August.

All captured chinook salmon were tagged, finclipped, measured, and released. A uniquely numbered metal tag was attached to the lower jaw of each fish. A combination of adipose, pectoral, and pelvic fin clips was used to identify the location and period of capture. Length was measured from mid-eye to fork-of-tail (ME-FK) to the nearest 5 mm. Sex was determined from observation of body morphology.

Recovery

Tags were recovered from chinook salmon carcasses from the same three river sections in which electrofishing was performed. Carcasses were collected starting with section 1 and ending with section 3. Section 1 required two days to complete (3 and 4 August) while sections 2 and 3 required one day (5 August).

One pass was made through each section in a drifting riverboat starting at the upstream end of each section. Long handled spears were used to collect carcasses. The carcasses were measured and examined for fin clips and jaw tags. The sex was determined from observation of body morphology. Three scales were removed from each of the first 560 carcasses for age analysis.

Abundance Estimator

The results from the mark-recapture experiment were investigated with a battery of statistical tests (described in the results) to determine the appropriate unbiased estimator. The estimated number of adult chinook salmon was calculated using a Darroch estimator (stratified by geographical location) for fish longer than 680 mm and a pooled Petersen estimator for fish less than or equal to 680 mm. The Darroch estimator is (Darroch 1961, cited in Seber 1982):

(1) $$\hat{N}^{\sim} = \mathbf{n}'\mathbf{M}^{-1}\mathbf{a}$$

where:

$\hat{N}^{\sim}$ = the estimated abundance of chinook salmon with length greater than 680 mm;

$\mathbf{n}$ = a vector of the number of carcasses of fish with length greater 680 mm recovered in sections 1, 2, and 3;

$\mathbf{M}^{-1}$ = a matrix of tag recoveries by river sections where the fish with length greater than 680 mm were marked and then recovered; and,

$\mathbf{a}$ = a vector of the number of fish marked and released in sections 1, 2, and 3.

The variance of $N^{\sim}$ was obtained using resampling techniques on the capture history (Efron and Gong 1983, and Buckland, unpublished). The capture history was created in two adjacent columns. The first column is the area where a fish was marked during electrofishing and the second column is the area where a fish was collected during the carcass survey. The numbers 1, 2, and 3 indicate the area that a fish was marked and/or collected. Each row represents the capture history of one fish. Zero was assigned in the appropriate column when a fish was not marked or not collected. The capture history was then sampled 500 times. The sample size equaled the number of rows in the original capture history. The matrix **M** and the vectors **a** and **n** were constructed from each sample of the capture history. The variance was then calculated as described by Buckland except that the Darroch estimator was substituted for the Petersen estimator.

The unbiased Petersen estimator and associated sampling variance are (described by Chapman 1951, cited in Seber 1982):

$$\hat{N}^{*} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \qquad (2)$$

$$\hat{V}(\hat{N}^{*}) = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \qquad (3)$$

where:

$\hat{N}^{*}$ = the estimated abundance of chinook salmon with length less than or equal to 680 mm;

n_1 = the number of fish with length less than or equal to 680 mm marked in the first sample;

n_2 = the number of fish with length less than or equal to 680 mm in the second sample; and,

m_2 = the number of marked fish with length less than or equal to 680 mm in the second sample.

The population abundance was then estimated as the sum of the estimates for large and small chinook salmon.

Tag Loss

The proportion of tags lost during the study and the associated variance were estimated using:

$$\hat{p}_t = n_u/n_r \qquad (4)$$

(5) $V(\hat{p}_t) = \hat{p}_t(1-\hat{p}_t)/(n_r-1)$

where:

$\hat{p}_t$ = the proportion of tags lost;

n_u = the number of recaptured fish without tags; and,

n_r = the total number of fish recaptured.

Age, Sex, and Size Composition

The proportion of females and males by ocean age and associated variance were estimated using:

(6) $\hat{p}_{ig} = a_{ig}/n_g$

(7) $V(\hat{p}_{ig}) = \hat{p}_{ig}(1-\hat{p}_{ig})/(n-1)$

where:

$\hat{p}_{ig}$ = the estimated proportion of females (or males) of ocean age i in sample g;

a_{ig} = the number of females (or males) of ocean age i in sample g;

n_g = the total number of females and males in the sample;

i = the ocean age (1, 2, 3, 4, and 5); and,

g = length greater than 680 mm, length less than or equal to 680 mm.

The abundance of females (or males) of ocean age i in the population was estimated using:

(8a) $\hat{N}_i = \sum_g \hat{p}_{ig}(\hat{N}^{\sim})$ or

(8b) $\hat{N}_i = \hat{p}_i(\hat{N}^*)$

The variance of the product N_i was estimated using Goodman's (1960) exact variance of products :

(9a) $V(\hat{N}_i) = \sum_g [N^{\sim 2}V(\hat{p}_i)+\hat{p}_i^{\,2}V(\hat{N}^{\sim})-V(\hat{p}_i)V(\hat{N}^{\sim})]$ or

(9b) $V(\hat{N}_i) = \sum_g [N^{*2}V(\hat{p}_i)+\hat{p}_i^{\,2}V(\hat{N}^*)-V(\hat{p}_i)V(\hat{N}^*)]$

Population Egg Production

The egg production for the Salcha River chinook salmon escapement and associated variance were estimated using:

(10) $\hat{E} = \sum \hat{N}_i \hat{F}_i$;

(11) $V(\hat{E}) = \sum V(\hat{N}_i \hat{F}_i)$; and

(12) $V(\hat{N}_i \hat{F}_i) = \hat{N}_i^2 V(\hat{F}_i) + \hat{F}_i^2 V(\hat{N}_i) - V(\hat{N}_i) V(\hat{F}_i)$

where:

$\hat{E}$ = the egg production for the escapement of the Salcha River chinook salmon;

$\hat{N}_i$ = the estimated number of females of ocean age i by size group g;

$\hat{F}_i$ = the mean fecundity for females of ocean age i as determined by Nelson and Biwer (1969) for chinook salmon in the Nushagak District of Bristol Bay (Table 1);

$V(\hat{E})$ = the variance of the population egg production;

$V(\hat{F}_i)$ = the variance of the mean fecundity for females of ocean age i;

$V(\hat{N}_i)$ = the variance of the estimated number of females of ocean age i.

Aerial Survey

Personnel from the Division of Commercial Fisheries of the Alaska Department of Fish and Game counted the number of live and dead adult chinook salmon in the Salcha River on three different occasions (20 July, 27 July, and 1 August). Counts were made from low flying, fixed-wing aircraft. Barton (1987c) describes the methods used by the Division of Commercial Fisheries for aerial surveys.

RESULTS

Four hundred fifty-nine chinook salmon were captured, tagged, and released from 26 July to 2 August. Four chinook salmon were killed during the capture event. Eight hundred seventy-three carcasses were collected and examined for tags and fin clips from 3 August to 5 August. Ninety-two of these fish were marked.

Tests of Assumptions for a Petersen Estimator

To determine if the sampling gear used during the carcass survey was size selective, a Kolmogorov-Smirnov goodness of fit test was used to compare the distributions of lengths of all fish that were marked during electrofishing (Figure 2) and then recaptured during the carcass survey. The length

Table 1. Mean lengths and mean fecundities by age for chinook salmon from the Nushagak District in Bristol Bay, 1967-1968 (Nelson and Biwer 1969).

Age[1]	Sample Size	Length[2] (mm)		Fecundity	
		mean	SE	mean	SE
1.3	10	776	8	8,358	387
1.4	46	884	8	10,299	315
1.5	13	974	14	12,214	569

[1] European formula "x.y" where "x" is the number of freshwater age minus one year and "y" is the ocean age. Total age equals x + y + 1.
[2] Mid-eye to fork-of-tail.

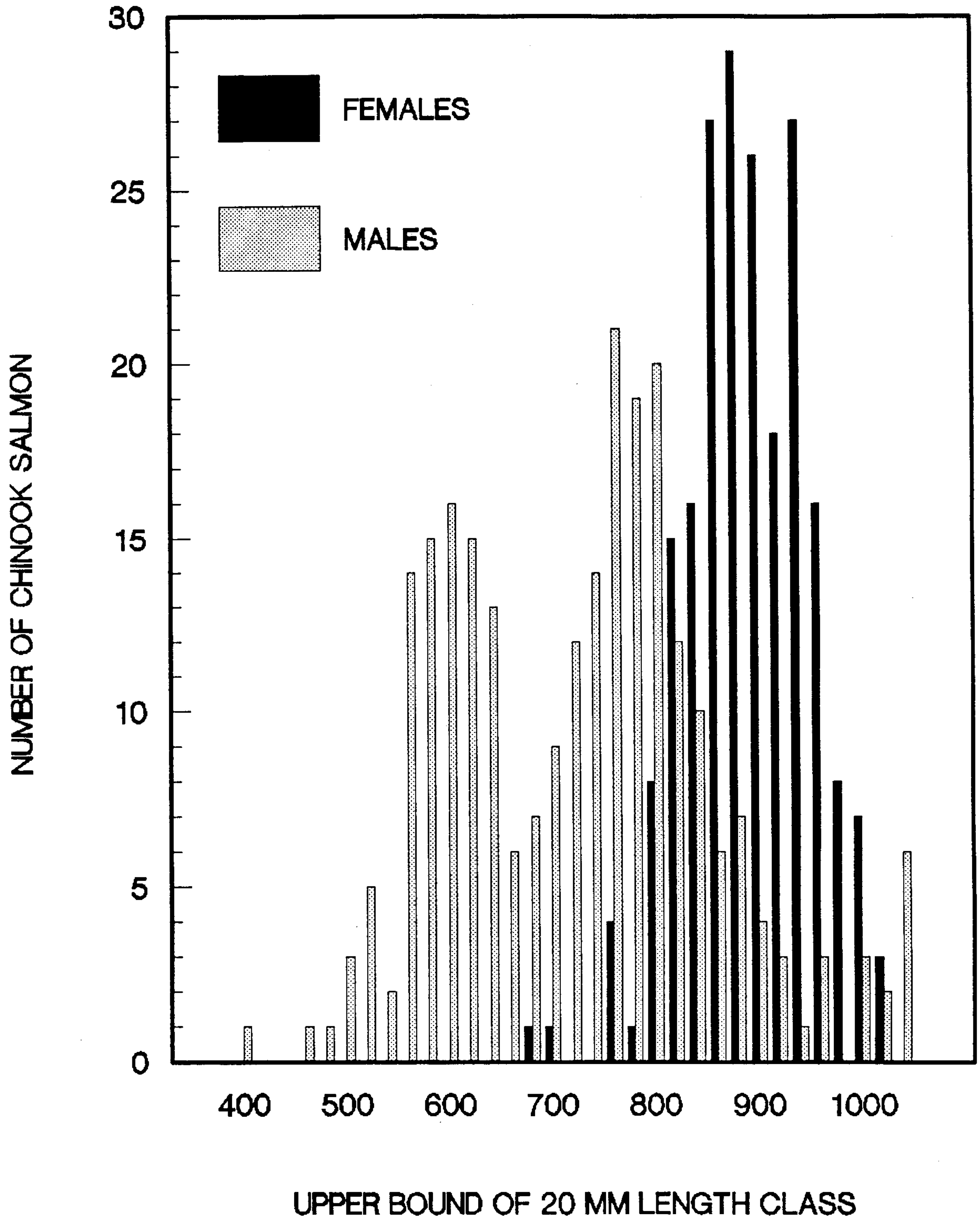

Figure 2. Distributions of the lengths of male and female chinook salmon captured using electrofishing gear during both marking events in the Salcha River.

distributions were significantly different (DN = 0.21, P = 0.003). The distributions of the lengths of marked and recaptured fish were bimodal. The modes were separated at 680 mm, the lowest point between the two modes, into large (length greater than 680 mm) and small (length less than or equal to 680 mm) size fish. The rate of recapture by size group was compared using the number of fish that were marked during electrofishing and later recaptured and not recaptured during the carcass survey. The rate of recapture was significantly different between large and small fish (χ^2 = 10.701, df = 1, P = 0.001; Table 2). A Kolmogorov-Smirnov goodness of fit test was then used to compare the length distributions of large fish that were marked during electrofishing and then recaptured during the carcass survey. The length distributions were not significantly different (DN = 0.14, P = 0.16). The test was repeated for the small fish. The length distributions were also not significantly different (DN = 0.26, P = 0.99). These tests indicate that there is no gear bias within the size groups and that stratification of the abundance estimate by length is appropriate.

A Kolmogorov-Smirnov two sample test was used to compare the length distributions of all fish that were marked during electrofishing and all collected carcasses. The length distributions were significantly different (DN = 0.17, P = 0.0032). The fish marked during electrofishing and the carcasses were also divided into large and small size fish. Each size group was tested using the Kolmogorov-Smirnov two sample test. The length distributions of the fish marked during electrofishing and the carcasses were not significantly different for the large (DN = 0.052, P = 0.54) and small (DN = 0.16, P = 0.12) fish. These tests also indicate that there is no gear bias within the size groups.

Although the rate of recapture was higher for females (0.24) than for males (0.17) this difference was not significant (χ^2 = 2.5, df = 1, P = 0.12; Table 3). Therefore, sex was ignored in stratifying the estimates of abundance.

The Chi-square statistic was used to evaluate mixing of marked fish between river sections. The number of marked fish that were recovered and were not recovered during the carcass survey were arranged in a contingency table. Rows 1, 2, and 3 are the river sections where marked fish were released. Columns 1, 2, and 3 are the river sections where marked fish were recovered. Column 4 is the number of marked fish that were not recovered (Tables 4, 5, and 6). Marked fish did not mix completely between sections (χ^2 = 138, df = 6, P = 0.001). The same test for just the large fish also indicated that fish did not mix completely between sections (χ^2 = 116, df = 6, P = 0.001).

The Chi-square statistic was used to evaluate the rates of recapture of marked fish by section. The number of marked fish that were recovered and were not recovered during the carcass survey were arranged by river section in a contingency table. The rates of recapture among the lower, middle, and upper carcass survey sections were significantly different (χ^2 = 17.56, df = 2, P = 0.0002; Table 7). The rates of recapture of just the large fish were also significantly different (χ^2 = 15.12, df = 2, P < 0.001; Table 8). The estimate of abundance of the large fish should be stratified by section using Darroch's model (1961) because the rates of recapture are different.

Table 2. Number of large (length > 680 mm) and small (length ≤ 680 mm) chinook salmon marked during electrofishing and recaptured and not recaptured during carcass sampling.

	Large	Small	Total
Recaptured	84	8	92
Not Recaptured	274	92	366
Total Released	358	100	458
Recovery Rate	0.23	0.08	

Table 3. Number of male and female chinook salmon that were recaptured and not recaptured during carcass sampling.

	Males	Females	Total
Recovered	43	49	92
Not Recovered	213	164	377
Total Released	256	213	469
Recovery Rate	0.17	0.23	

Table 4. Recapture history by river section of all chinook salmon that were tagged in three sections of the Salcha River.

Recaptured fish only				
River section where marks were released	River section where marks were recaptured			
	Lower	Middle	Upper	Total
Lower	38	0	0	38
Middle	3	17	0	20
Upper	1	8	25	34
Total	42	25	25	92

River Section	Number of fish collected during carcass survey	
	Sample Size	Not marked
Lower	443	401
Middle	165	140
Upper	265	240
Total	873	781

Table 5. Recapture history by river section of large (length > 680 mm) chinook salmon that were tagged in three sections of the Salcha River. These data were used to estimate abundance of large chinook salmon with Darroch's estimator.

	Recaptured fish only			
River section where marks were released	River section where marks were recaptured			
	Lower	Middle	Upper	Total
Lower	36	0	0	36
Middle	3	17	0	20
Upper	1	8	19	28
Total	40	25	19	84

	Number of fish collected during carcass survey	
River Section	Sample Size	Not marked
Lower	357	317
Middle	142	117
Upper	233	214
Total	732	648

Table 6. Recapture history by river section of small (length ≤ 680 mm) chinook salmon that were tagged in three sections of the Salcha River. These data were used to estimate abundance of chinook salmon with Chapman's estimator.

River section where marks were released	Recaptured fish only: River section where marks were recaptured			
	Lower	Middle	Upper	Total
Lower	2	0	0	2
Middle	0	0	0	0
Upper	0	0	6	6
Total	2	0	6	8

River Section	Number of fish collected during carcass survey: Sample Size	Not marked
Lower	86	84
Middle	23	23
Upper	32	26
Total	141	133

Table 7. Number of marked chinook salmon that were and were not recovered during carcass sampling by river section.

	River Section			
	Lower	Middle	Upper	Total
Recovered	42	25	25	92
Not Recovered	88	122	157	367
Total Collected	130	147	182	459
Recovery Rate	0.32	0.20	0.14	

Table 8. Number of large (length > 680 mm) marked chinook salmon that were and were not recovered during carcass sampling by river section.

	River Section			
	Lower	Middle	Upper	Total
Recovered	40	25	19	84
Not Recovered	73	88	113	274
Total Collected	113	113	132	358
Recovery Rate	0.35	0.22	0.14	

The Chi-square statistic was used to evaluate the rates of capture of marked and unmarked fish by river section. The number of marked and unmarked fish collected during the carcass survey were arranged by river section in a contingency table. The rates of capture among the lower, middle, and upper carcass survey sections were not significantly different (χ^2 = 4.59, df = 2, P = 0.10; Table 9). However, when the rates of capture of just the large fish were examined the differences were significant (χ^2 = 7.81, df = 2, 0.025 > P > 0.01; Table 10) which supports the use of Darroch's model. Because the boundary between the upper and middle sections bisects a major spawning section I combined the data for these sections. The rates of recapture were not significantly different between the lower section and the combined middle and upper sections (χ^2 = 0.05, df = 1, 0.90 > P > 0.75). I was not able to analyze the rate of capture of the small fish because only eight marked fish were recovered.

The Chi-square statistic was used to evaluate the rates of recapture of marked fish by marking event. The number of marked fish that were recovered and were not recovered during the carcass survey were arranged in a contingency table by the first and second marking events (26 to 30 July and 1 to 2 August, respectively). The rates of recapture were not significantly different (χ^2 = 1.62, df = 1, 0.25 > P > 0.10); Table 11). The rates of recapture of large and small fish were also not significantly different (χ^2 = 0.25, df = 1, 0.75 > P > 0.50; and χ^2 = 0.01, df = 1, 0.95 > P > 0.90). Therefore, stratification of the abundance estimate by time was not necessary for either the large or small fish.

Abundance Estimate

Based on the results of the previous tests, I first stratified the fish into two size groups; fish having lengths greater than 680 mm and those having lengths less than or equal to 680 mm. Abundance of large fish was estimated using Darroch's method to adjust for unequal recapture rates among the three river sections. Because too few fish were recaptured to use Darroch's method, the abundance of small fish was estimated using a pooled Petersen estimator.

The estimated abundance of large and small fish was 2,969 (SE = 303) and 1,593 (SE = 465), respectively. The estimated abundance of the population (large and small fish combined) was 4,562 (SE = 556).

Tag Loss

Because all marked fish received both a metal jaw tag and a fin clip, I was able to estimate the proportion of tags lost during the mark recapture experiment. Ninety-two marked chinook salmon carcasses were recovered; 82 had tags, and 10 had only a fin clip. The estimated proportion of tags lost during the mark-recovery experiment was 0.11 (SE = 0.033).

Age, Sex, and Size Composition

Length and sex data of chinook salmon were obtained during both marking events and during carcass recovery. Of 459 fish that were captured during both

Table 9. Number of marked and not marked chinook salmon collected during carcass sampling by river section.

	River Section			
	Lower	Middle	Upper	Total
Marked	42	25	25	92
Not marked	401	140	240	781
Total Collected	443	165	265	873
Recovery Rate	0.095	0.15	0.094	

Table 10. Number of marked and not marked large (length > 680 mm) chinook salmon collected during carcass sampling by river section.

	River Section			
	Lower	Middle	Upper	Total
Marked	40	25	19	84
Not marked	317	117	214	648
Total Collected	357	142	233	732
Recovery Rate	0.11	0.18	0.08	

Table 11. Number of chinook salmon that were marked during the first and second marking events and recaptured and not recaptured during carcass sampling.[1]

	First	Second	Total
Recaptured	51	41	92
Not Recaptured	230	137	367
Total Released	281	178	459
Recovery Rate	0.18	0.23	

[1] The first marking event was 26 - 30 July; the second marking event was 1 - 2 August.

marking events, 208 were females and 251 were males, for a sex ratio of 0.83 to 1, which is the about the same sex ratio found in 1987 (Skaugstad 1988). During carcass sampling, 423 females and 448 males were collected, for a sex ratio of 0.94 to 1.

The sex ratios are much different when the abundance estimates for the large and small fish are used. For large fish there were 1,496 (SE = 145) females and 1,473 (SE = 131) males. The sex ratio was about 1 to 1. For small fish there were 29 (SE = 20) females and 1,564 (SE = 392) males. The sex ratio was about 0.01 to 1. When large and small fish were combined the estimated number of females and males was 1,525 (SE = 146) and 3,037 (SE = 413), respectively. The sex ratio was about 0.50 to 1.

During carcass sampling, age, sex, and length data were obtained from 497 chinook salmon. Ocean ages of these fish ranged from 1 through 5 years and nearly all fish spent just one year in freshwater (Tables 12 and 13). The dominant age class for females was 1.4 (brood year 1982) and for males was 1.2 and 1.3 (brood years 1984 and 1983). About 93 percent of the females were age 1.4 or older and about 66 percent of the males were age 1.2 or 1.3. The length of females ranged from 670 to 1,100 mm; males ranged from 380 to 1,080 mm (Table 14). There was no consistent trend for females to be larger on average than males.

Population Egg Production

The estimate of egg production was 16.2 million eggs (SE = 2.8 million; Table 15). Age class 1.4 females accounted for about 67 percent of the population egg production.

Effects of Electrofishing

Only four chinook salmon were killed while using the electrofishing gear. The only fish that showed signs of extreme stress or that were killed during marking were spawned out females or males that were in poor physical condition. These fish also took longer to recover after being shocked. I expect that these fish were within 1 or 2 days of a natural death and that they took longer to recover because they were dying.

I had intended to investigate the effects of electrofishing on mature female chinook salmon by examining the carcasses of females for unspawned eggs. I was not able to do this because about 70 percent of the females captured during both marking events were partially or fully spawned out. During the carcass, survey no carcasses of unspawned females were found.

Aerial Survey

Aerial survey counts of chinook salmon in the Salcha River were made on 20 July, 27 July, and 1 August (Table 16). Survey conditions were rated as "excellent", "good", and "fair", respectively, on a scale of "poor, fair, good, and excellent". The maximum count was on 27 July (2,655 live and 106 dead chinook salmon) and coincided with the first marking event. The combined

Table 12. Estimates of proportion and abundance of large (length > 680 mm) female and male chinook salmon by age class in the Salcha River, 1988.

Females					
Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
1.1	0				
1.2	1	0.003	0.003	8	8
1.3	12	0.031	0.009	92	28
1.4	135	0.35	0.024	1,036	128
1.5	47	0.12	0.017	361	61
Totals	195	0.50		1,496	145

Males					
Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
1.1	0				
1.2	10	0.026	0.008	77	25
1.3	86	0.22	0.021	660	92
2.2	0				
1.4	70	0.18	0.020	537	80
1.5	25	0.065	0.013	192	42
2.4	1	0.003	0.003	8	8
Totals	192	0.50		1,473	131

Table 13. Estimates of proportion and abundance of small (length ≤ 680 mm) female and male chinook salmon by age class in the Salcha River, 1988.

Females					
Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
1.1	0				
1.2	0				
1.3	1	0.009	0.009	14	14
1.4	1	0.009	0.009	14	14
1.5	0				
Totals	2	0.018		29	20

Males					
Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
1.1	2	0.018	0.013	29	21
1.2	90	0.82	0.037	1,303	385
1.3	12	0.12	0.030	174	68
2.2	1	0.009	0.009	14	14
1.4	3	0.027	0.016	43	27
1.5	0				
2.4	0				
Totals	192	0.982		1,564	392

Table 14. Length at age of chinook salmon collected during carcass surveys of the Salcha River, 1988.

Females:

Age Class	Sample Size	Length (mm) Mean	SE	Range
1.1	0			
1.2	1	790		
1.3	13	810	20	670 - 940
1.4	136	870	4	780 - 990
1.5	47	952	8	830 - 1,100
Total	197			

Males:

Age Class	Sample Size	Length (mm) Mean	SE	Range
1.1	2	390	15	380 - 410
1.2	100	590	6	440 - 780
1.3	98	740	6	570 - 890
2.2	1	650		
1.4	73	860	10	590 - 1,060
1.5	25	990	15	700 - 1,080
2.4	1	850		
Total	300			

Males and Females Combined:

Age Class	Sample Size	Length (mm) Mean	SE	Range
1.1	2	390	15	380 - 410
1.2	101	600	6	440 - 790
1.3	111	750	6	570 - 940
2.2	1	650		
1.4	209	870	4	590 - 1,060
1.5	72	960	8	700 - 1,100
2.4	1	850		
Total	497			

Table 15. Estimate of egg production by age class of Salcha River chinook salmon, 1988.

Age Class	Estimated Number of Females	Average Fecundity[1]	Estimated Number of Eggs (millions)	SE
1.2 + 1.3	114	8,358	0.95	0.29
1.4	1,050	10,299	10.8	2.6
1.5	361	12,214	4.4	1.0
Totals	1,525		16.2	2.8

[1] From Nelson and Biwer (1969).

Table 16. Abundance of live and dead chinook salmon counted during aerial surveys of the Salcha River, 1988 (Barton, Personal Communication).

Date	Live	Dead	Survey Conditions
20 July	2,200	11	Excellent
27 July	2,655	106	Good
1 August	829	210	Fair

count of 2,761 was about 61 percent of the point estimate from the mark-recapture experiment.

DISCUSSION

Examination of the data from the mark-recapture experiment indicate that there was only partial mixing of fish between sections. Marked fish were recovered in the section where they were marked or in sections downstream from where they were marked; however, no marked fish was recovered in a section upstream from where it was marked. When marked, most fish had finished or nearly finished spawning and were a few days from death. Dying fish would be less able to maintain a stationary position and would probably drift downstream into areas with pools and lower velocities. The different rates of recapture of marked fish by section were probably a result of fish drifting into the lower sections. The different rates of capture of marked and not marked fish by section are probably an artifact of the location of the boundary between the upper and middle sections. The boundary bisects one of the major spawning sections of the Salcha River. Spawned out fish that were in poor condition when marked in the upper section may have drifted into the upper end of the middle section. The rates of capture between the lower section and the combined middle and upper sections are not different, which supports my hypothesis.

Stratification of the estimate of abundance by section may not be necessary when the probability of movement is equal for all fish. Also, the different rates of recovery of marked fish may be an artifact of the test when the population is divided into sections by arbitrary boundaries. When there is a constant probability of capture over the whole population when the fish are initially caught for marking and the movement pattern for marked and not marked fish is the same, then the estimates of abundance using Petersen's model and Darroch's model are about the same. The estimate of abundance using Chapman's modification of the Petersen model, stratified for large and small fish, is 4,322 (SE = 376). The estimates of abundance using Chapman's and Darroch's models are not significantly different (difference = 240, $P > 0.50$).

The rate of recapture of small fish during carcass surveys was less than the rate of recapture of large fish. The carcasses of small fish, when covered with silt, are not as visible as the carcasses of large fish and are more difficult to distinguish from broken tree limbs on the river bottom.

Fish counts made during an aerial survey are usually lower than estimates obtained during mark-recapture experiments for a number of reasons including: fish may still be arriving; fish may have died and been washed from the river; or not all of the fish present are visible because of weather conditions, water level, water clarity, and overhanging vegetation. For the Salcha River in 1987, the number of fish counted during an aerial survey was 40 percent of the abundance estimated by a mark-recapture experiment (Skaugstad 1988). The higher percentage of fish counted in the Salcha River in 1988 (similar population size during both years) is probably due to better visibility during the 1988 survey. During the 1988 aerial survey the Salcha River was clear and light conditions were better which probably resulted in more of the population being visible.

This is the second year that an estimate of abundance of Salcha River chinook salmon from a mark-recapture experiment has been compared to a count from an aerial survey. My objective is to estimate the proportion of the population observed during an aerial survey based on the subjective evaluation of the water and weather conditions during the survey. The estimate of the proportion of the population observed can then be used to estimate the population abundance from past and future aerial surveys. Additional comparisons are still required to refine the relationship between the proportion of the population observed during an aerial survey and the subjective evaluation of the aerial survey.

Based on 2 years of sampling, I have shown that electrofishing is an efficient method of capturing chinook salmon. Very few fish have been killed and the potential harm to unspawned females is low because electrofishing was used after most of the females had spawned. I recommend the continued use of electrofishing to capture chinook salmon in the Salcha River.

ACKNOWLEDGEMENTS

I wish to thank Betsy McCracken, Tom Kerns, Rolland Holmes, John H. Clark, Alan Burkholder, William Arvey, Robert Conrad, and Lawrence Buklis for assisting with the collection of data in the field. Thanks to John Wilcock and crew for collecting tissue samples and assisting with other field activities. Special thanks to John H. Clark, Rolland Holmes, and David Bernard for reviewing and editing the manuscript and providing valuable suggestions. Appreciation is given to John Wilcock for scale reading and the age summaries used in this report. Funding for this project was provided through the United States - Canada Pacific Salmon Treaty, Yukon River, cooperative agreement number NA-88-ABH-00045.

LITERATURE CITED

Barton, L. H. 1984. A catalog of Yukon River salmon spawning escapement surveys. ADF&G technical data report number 121. Alaska Department of Fish and Game, Division of Commercial Fisheries. 472 pp.

______. 1987a. Population size and composition of chinook salmon spawners in a small interior Alaska stream, 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks. Arctic, Yukon, and Kuskokwim Region, Yukon salmon escapement report number 32. 18 pp.

______. 1987b. Population estimate of chinook salmon escapement in the Chena River in 1986 based upon mark and recapture techniques. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks. Arctic, Yukon, and Kuskokwim Region, Yukon salmon escapement report no. 31. 38 pp.

_____. 1987c. Yukon area salmon escapement aerial survey manual. Arctic, Yukon, and Kuskokwim Region, Yukon River salmon escapement report number 33, Alaska Department of Fish and Game. 14 pp.

Buckland, S. T. Unpublished. Quantifying precision of mark-recapture estimates using the bootstrap. Inter American Tropical Tuna Commission, 8604 La Jolla Shores Drive, La Jolla, California, 92093.

Clark, R. A. 1985. Evaluation of sampling gears for fish population assessment in Alaska lakes. Masters Thesis. University of Alaska, Fairbanks, Alaska. 180 pp.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1, pp. 131-160.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48, pp. 241-260.

Efron, B. and G. Gong. 1983. A leisurely look at the bootstrap, the jackknife, and cross-validation. The American Statistician, 37(1). 48 pp.

Goodman, L. A. 1960. On the exact variance of products. Journal of American Statistical Association. Volume 55, pp. 708-713.

Nelson, M. L. and D. A. Biwer. 1969. Compilation of notes and biological data from the Nushagak and Togiak districts, Bristol bay, 1967-1968. Alaska Department of Fish and Game, Division of Commercial Fisheries. Bristol Bay Data Report Number 9. 34 pp.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Company, Ltd. 654 pp.

Skaugstad, C. L. 1988. Abundance and age-sex-size composition of the 1987 Salcha River chinook salmon escapement. Fishery Data Series No. 37. Alaska Department of Fish and Game. Division of Sport Fish. Juneau. 25 pp.